

ON POSSIBILITY OF HIGGS MECHANISM BREAK DOWN DUE TO THE INSTANTONS

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ABSTRACT

Two-dimensional Abelian Higgs model is considered. It is shown that Higgs mechanism of the gauge bosons masses generating is broken in presence of instantons. It is supposed that discussion can be generalized into the standard model of electroweak interactions.

1 Introduction

It is well known that some field theories (including QCD and Weinberg-Salam model) have the degenerated vacuum structure on the classical level [1]. Unequivalent classical vacua are characterized by different Chern-Simons numbers N and separated by the energy barriers. Amplitude of the tunneling through these barriers is nonzero if the theory admits instantons [2, 3] (classical finite-action Euclidean solutions). Thus classical degeneration disappears due to the instantons. The correct vacuum state is approximately linear combination of the naive classical vacua with different N .

Ordinary perturbative theory corresponds to the $N = 0$. It is quite naturally that taking into account of the another vacua with $N \neq 0$ leads to the essential consequences. Let us remind the most important of them.

1. Instantons lead to the charge confinement in the 2-dimensional Abelian Higgs model [4] and 3-dimensional non-Abelian Higgs model [5].

2. In the electroweak theory instantons induce baryon and lepton numbers violation [3] which can be connected with the matter and antimatter asymmetry of the Universe [6].

3. In QCD instantons lead to the quark and gluon condensates formation, spontaneously break chiral symmetry, solve $U(1)$ -problem [3]. It was suggested

that QCD-instantons can be produced in deep-inelastic scattering [7] and identified by means of the analysis of the final states at HERA(DESY) [8].

We would like to attract an attention to the once more consequence of the instantons. It is known that in the Weinberg-Salam theory [9] W^\pm and Z^0 bosons get the masses due to the interaction with Higgs fields, which have nonzero vacuum expectation value and spontaneously break local $SU(2)$ symmetry [10]. However Higgs mechanism of the masses generating is perturbative phenomenon and it is violated, for example, at a temperature higher than about 10^3 GeV [11] what could occur at the early Universe. At high temperature local $SU(2)$ symmetry is restored and W^\pm and Z^0 bosons become massless. In this letter we demonstrate that Higgs mechanism is broken down even at *zero temperature* if we take into account instanton tunneling transitions. In sections 2 and 3 the example of 2-dimensional Abelian Higgs model is considered. Section 4 is devoted to the possibility of Higgs mechanism violation in Weinberg-salam theory.

2 Local gauge symmetry restoration owing to the existence of the instantons

Abelian Higgs model describes the interactions of the real vector fields $A_\mu(t, x)$ and self-interacting complex scalar fields $\phi(t, x)$:

$$L = -\frac{1}{4}F_{\mu\nu}F_{\mu\nu} + \frac{1}{2}(D_\mu\phi)^*D_\mu\phi - \lambda(\phi^*\phi - \rho^2)^2, \quad (1)$$

$$D_\mu = \partial_\mu - ieA_\mu, \quad F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu, \quad \mu, \nu = 0, 1; \quad \lambda > 0, \quad \rho > 0.$$

There are the following classical vacua:

$$A_\mu(t, x) = \frac{1}{e}\partial_\mu\alpha(t, x), \quad \phi(t, x) = e^{i\alpha(t, x)}\rho. \quad (2)$$

In the perturbative approach vacuum $A_\mu(t, x) = 0$, $\phi(t, x) = \rho$ is chosen. Lagrangian for the small perturbations near this vacuum

$$L = -\frac{1}{4}F_{\mu\nu}F_{\mu\nu} + \frac{e^2\rho^2}{2}A_\mu A_\mu + \frac{1}{2}e^2A_\mu A_\mu(2\eta\rho + \eta^2) + \frac{1}{2}\partial_\mu\eta\partial_\mu\eta - 4\lambda\eta^2\rho^2 - 4\lambda\eta^3\rho - \lambda\eta^4, \quad \eta(t, x) = |\phi(t, x)| - \rho \quad (3)$$

describes the *massive* gauge field and 1-component scalar field. It is said that the second component of Higgs field is "eaten" by the gauge field, which gets the mass $e\rho$.

It should be noted that nonzero value of the gauge bosons masses is a consequence of the spontaneously symmetry breaking characterized by the perturbative vacuum expectation value $\langle \phi \rangle = \rho$. If the symmetry is unbroken ($\rho = 0$) there are massless bosons and 2-component scalar field.

As it was mentioned above all classical vacua (2) fall into distinct classes, which are characterized by an integer parameter N (Chern-Simons number) [4]. Nielsen-Olesen vortices [12] play role of the instanton solutions in this theory. Therefore different vacuum states $|N\rangle$ can be connected to each other by means of tunneling transitions. Thus the correct vacuum is [1, 4]

$$|\Theta\rangle \approx \sum_{N=-\infty}^{+\infty} e^{iN\Theta} |N\rangle. \quad (4)$$

Nonzero value $\langle\phi\rangle = \rho$ characterizes naive perturbative vacuum with $N = 0$ only. At the same time for the correct vacuum $|\Theta\rangle$ the scalar field expectation value is zero [4]:

$$\begin{aligned} \langle\Theta|\phi|\Theta\rangle &\approx \sum_{N,M=-\infty}^{+\infty} e^{i(N-M)\Theta} \langle M|\phi|N\rangle = \\ &= \sum_{N=-\infty}^{+\infty} \langle N|\phi|N\rangle + O(e^{-S_{inst}}) \approx \rho \sum_{N=-\infty}^{+\infty} e^{i\alpha_N(x)} = 0. \end{aligned} \quad (5)$$

where $S_{inst} \sim \rho$ is Euclidean instanton action, $\alpha_N(x)$ is a set of the static configurations which characterizes unequivalent vacua if $A_0(t, x) = 0$ and $e^{\alpha_N(\pm\infty)} = 1$.

The result (5) means that *effective* potential for Higgs field has only one minimum unlike classical potential. This situation corresponds to the effective theory with zero mass gauge field and 2-component scalar field.

3 Screening of the confinement by the unlike-charged particles production

It is well known that confinement phenomenon exists in the 2-dimensional Abelian Higgs model [4]. Let one introduce two static external charges by means of Wilson procedure [13]. We suppose that the interaction between external charges and gauge field is described by the adding to the Lagrangian the term $j_\mu A_\mu$. The energy of the attraction between external charges is given by the following formula (see for review [14]):

$$E_\Theta(R) \sim e^{-S_{inst}} R \left[\cos\Theta - \cos\left(\Theta + \frac{2\pi q}{e}\right) \right], \quad (6)$$

where R is a distance between two external particles with the charges $+q$ and $-q$.

If $q = Ne$ the attraction disappears. It can be interpreted as a screening of the external charges by means of the unlike-charged scalar particle pairs production. However description of such charged particles requires two-component

field. Because of the total number of the independent field components is conserved the theory possesses *massless* gauge field only. This statement contradicts with perturbative Higgs mechanism. Thus possibility of the screening of the confinement confirms the result of the previous section.

4 Conclusion

As it is well known Higgs mechanism are used in Weinberg-Salam theory for the W^\pm and Z^0 bosons masses generating. However there are not any experimental confirmation of Higgs bosons existing. Let us suppose that our results can be generalized into Weinberg-Salam theory. If instantons are not gauge and lattice artifacts that standard model of electroweak interactions contains massless gauge bosons and charged scalar (Higgs) particles instead of the experimentally observed massive gauge bosons. This argument leads to the necessity of the using of an alternative mechanism of the W^\pm and Z^0 bosons masses generating without additional Higgs fields.

It should be noted, that in Weinberg-Salam theory instanton transitions are strongly suppressed by the 't Hooft factor [3]:

$$e^{-2S_{inst}} = e^{-\frac{4\pi}{\alpha_w}} \sim 10^{-160}. \quad (7)$$

However for the enough long time intervals the instanton processes probability can increase

$$P \propto e^{-\frac{4\pi}{\alpha_w}} \int dt_0 dx_0 \quad (8)$$

if we take into account the integration on the centre of the instanton t_0, x_0 which is arbitrary space-time point. For $t > e^{\frac{4\pi}{\alpha_w}}$ the probability of the instanton transitions is not negligible. Thus instantons can restore gauge symmetry and violate Higgs mechanism.

It is interesting that instantons can dynamically break the gauge symmetry and thus provide an alternative to the Higgs mechanism [15].

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